WILDLIFE DAMAGE AND CONTROL IN

OKLAHOMA PECAN ORCHARDS

By

THOMAS CHRISTOPHER HALL

Bachelor of Arts
Fort Lewis College
Durango, Colorado
1979

Bachelor of Science
Fort Lewis College
Durango, Colorado
1979

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1984

WILDLIFE DAMAGE AND CONTROL IN

OKLAHOMA PECAN ORCHARDS

Thesis Approved:

Thesis Adviser

Dean of the Graduate College

PREFACE

This study was conducted to determine the effectiveness of 2 control techniques for wildlife, and to monitor wildlife damage and ecology in pecan orchards of Oklahoma. My study hopefully provides data which will benefit the pecan industry and future research. Financial support was provided by the Oklahoma State University (OSU) Horticulture and Landscape Architecture Department, OSU Agricultural Experiment Station and the Oklahoma Cooperative Wildlife Research Unit.

Dr. Frank Schitoskey was my major adviser. His guidance was sincerely appreciated. Dr. Michael Smith served on my committee and assisted me with numerous problems encountered in the study. Dr. Larry Talent also served on my committee and provided helpful advice. I wish to thank them for their help and improvements on my study and thesis manuscripts.

Drs. Dave Otis, Ronald McNew and William Warde provided counsel on statistical design and analyses. Ed Shafer, Joseph Guarino and other Denver Wildlife Research Center staff provided much input into the study. Several others were responsible for initiating the project. I would like to thank them.

I wish to extend my gratitude to Ronald Mount, and Bill and Scott Landgraf for use of their orchards. These growers and their families were a tremendous help during the study. They provided technical advice on pecan culture, many hours of enjoyment and home-cookin' that I couldn't pass up.

I am grateful to Judy Gray, other Oklahoma Cooperative Wildlife Research Unit personnel and graduate students for their support. Also, I would like to thank my technicians M. Earl Stewart and Doug Gottschalk for their work in the field. I am indebted to Earl and friends for the occassional hunting trips and morale boosters needed to make it through grad school.

Finally, I thank family and friends for their support. Especially, I would like to thank my fiancee, Maureen, for her help and for waiting endlessly in Denver while I finished school.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The project for this thesis was to evaluate the effectiveness of 2 techniques for alleviating pecan losses caused by blue jays (Cyanocitta cristata) in native orchards in Oklahoma. However, information was collected on all wildlife that could potentially cause pecan losses. Much information was also collected from control orchards and during general observations on wildlife damage ecology.

This thesis is written in chapter format. Chapter II, "Literature Review," covers the basic pecan industry, wildlife depredation and control, and blue jay ecology in pecan orchards. Chapter III, "Hinder as a Wildlife Repellent in Pecan Orchards," discusses a pilot study to determine the usefulness of Hinder for pecans. Chapter III is written in laboratory report form following the format used by the Denver Wildlife Research Center. Chapter IV, "Evaluation of Two Wildlife Control Techniques in Oklahoma Pecan Orchards," evaluates sound-scare devices and the application of the avian repellent, methiocarb. Chapter V, "Wildlife Damage Ecology in Pecan Orchards," provides information on damage ecology for all wildlife species in the United States and particularly for species in Oklahoma. Chapters IV and V are manuscripts written in Journal of Wildlife Management style.

CHAPTER II

LITERATURE REVIEW

Wildlife can have a significant impact on pecan production. Although wildlife cause millions of dollars of pecan damage annually, little information exists on the effectiveness of damage control techniques. This chapter reviews pecan production procedures and animal damage control techniques that have been evaluated for pecans. The blue jay (Cyanocitta cristata) problem in native pecan orchards in Oklahoma is discussed as justification for research.

Pecan Production

Pecans are native to the southern Mississippi River valley and its tributaries. The cultural range extends beyond the native range into New Mexico, Arizona, Alabama, Georgia, Florida, North Carolina, South Carolina and other regions of the world (Jaynes 1979). The United States produces over 90 million kilograms of pecans annually (Shafer and Bailey 1978).

Pecans are divided into 2 categories, natives (seedlings) and cultivars (papershells). Native pecans vary in size and are generally marketed as piecemeal. Maturation ranges between 120 and 250 days for pecans on individual trees. Cultivars are uniform in size within a cultivar and frequently sold as whole nuts. Maturation occurs approximately at the same time for each cultivar, but maturation time

varies between cultivars (Woodroof 1979). Cultivars sell at a higher price per pound and produce greater yields than natives.

Oklahoma produces approximately 7 million kilograms of pecans annually. Approximately 85% of the production is native pecans. Because several areas are increasing pecan production, and cultivars are replacing native trees, production in Oklahoma is expected to increase.

Ripening of pecans in Oklahoma starts in late September and continues to November. Harvesting is initiated in early November and may not be completed until February. Trees or limbs are shook with mechanical shakers to harvest pecans, causing ripe nuts to fall to the ground. These are swept up with a mechanical sweeper, cleaned, sorted and packaged for marketing. Trees are shook after most nuts have ripened. Harvesting cultivars is similar except that they may be harvested soon after the first nut ripens.

Pecan loss occurs directly or indirectly from several sources. Uncontrollable weather conditions such as drought and ice storms create significant problems to growers. Insects and diseases cause damage to mature trees from bud break through ripening and are controlled with pesticides. Woodroof (1979) gives life histories and methods of control for major disease and insect pests of pecans.

Vertebrate pest damage to pecans results in the loss of millions of dollars annually in the United States. Georgia growers estimate 4.5 million kilograms are lost annually (Carlton 1975). Oklahoma pecan growers attribute an annual loss of 0.9 million kilograms to wildlife (Leppla 1980). Individual growers receive variable amounts of losses, but in some cases loss can reach 100%.

Many pecan orchards occur in close proximity to woodlands,

primarily oaks (Quercus spp.). This makes orchards more vulnerable to depredation because woodlands provide cover and roost sites for wildlife. Paradoxically, many wildlife species such as blue jays prefer oak mast (acorns) to pecans, and the severity of pecan damage is generally inversely proportional to acorn production. This was true in 1977 and 1981 when wildlife damage to pecans was light and acorn production was high. Therefore, woodlots can be advantageous for growers to maintain. Thus, the relationship of woodlots to pecan damage is variable.

Animal Damage Control for Pecans

Several species of wildlife are responsible for damage in pecan orchards. Martin et al. (1951) list 25 mammals and birds which consume pecans. Common depredators are blue jays, common crows (Corvus brachyrhynchos), red-bellied woodpeckers (Melanerpes carolinus), red-headed woodpeckers (M. erythrocephalus), common flickers (Colaptes auratus), eastern fox squirrels (Sciurus niger), gray squirrels (S. carolinensis), raccoons (Procyon lotor), white-tailed deer (Odocoileus virginianus) and eastern woodrats (Neotoma floridana). In Oklahoma, blue jays, crows, red-bellied woodpeckers, red-headed woodpeckers and eastern fox squirrels were the most significant depredators, causing about 25% annual damage with control methods in use (Leppla 1980). Crows were the major pecan depredator in Louisiana, causing about 6% annual damage (Murray 1975).

Blue jays, crows and squirrels are the major pests in pecan orchards of the United States (Livingston 1973, Carlton 1975) and Oklahoma (Couch et al. 1977). Blue jays are major depredators in native

pecan orchards, especially in the southern plains states. Crows are major depredators in cultivar orchards in southeastern states. These 2 species are hardest to control in the respective orchard types. Squirrels are a problem in orchards where population densities are high which occurs mostly in mature orchards.

Control Methods

Many control methods have been used to rid pecan orchards of depredators. None are 100% effective although most alleviate the problem somewhat and possibly provide economic gains for the grower. Several control methods should be incorporated at the same time for effective damage control. Growers should anticipate damage and be prepared. The economics of different control methods should be analyzed to determine which methods to use.

Direct Control

Most animal damage control methods in use today are direct control measures, which is the actual reduction of target populations. Population reduction may or may not involve killing.

Poisons. Poisons are available for rodent control. Zinc phosphide is used on baits which are normally placed in burrows and runways under vegetation to minimize danger to non-target species (Kennamer 1959, Carlton 1975). The chemical must be applied with care and dead animals disposed of properly. Fumigants (Jaynes 1979) and anticoagulants (Carlton 1975) are also used as rodenticides.

Shooting. Shooting can be an effective method to alleviate damage

in pecan orchards from mammals such as squirrels and deer. Growers can sell hunting permits to offset damage loss, invite hunters to use their orchard, or shoot unwanted pests themselves. Shooting is generally accepted as the best method of squirrel control (Strother and McVay 1978).

Shooting is not recommended for bird control (Evers and Callahan 1954, Larsen 1971). It is often better to use shooting in conjunction with other control techniques. Crow shooting, though, is a popular sport and growers may benefit from encouraging such activities. Kenworthy (1954) suggested the use of calls, blinds and a .22 caliber rifle for alleviating some crow damage.

Growers must be aware that laws protect all vertebrate species damaging pecans. Thus, growers must obtain the appropiate permits to kill depredators: 1) from the U. S. Fish and Wildlife Service for migratory birds, and 2) from local Game and Fish agents for all species.

Trapping. Trapping is usually an ineffective method of control in pecans because baits must lure animals to traps at a time when food is plentiful. Live traps have been used for crows (Woodbury 1961, Wilson 1974), blue jays (Livingston 1973) and squirrels (Carlton 1975, Strother and McVay 1978) with little success in pecan orchards. However, kill and leg-hold traps are more successful with squirrels (Reed 1973). Growers can also trap raccoons, opossum (Didelphis virginiana) and beavers (Castor canadensis). Permits must be obtained to use traps.

Scare devices. Many scare devices are available for growers: acetylene exploders, rope firecrackers, crackershells, whistle bombs, biosonics (recorded distress calls, AV-alarms, recorded noises) and

scarecrows (aluminum, stuffed owls, helium balloons). These devices are effective only for short term control unless they are started early, set in close proximity, moved frequently, have blasts varied and have some individuals killed for reinforcement (Carlton 1975).

Electronic scare devices appear to be the most effective for birds (Strother and McVay 1978) and most economical (Boulvell 1979) method of control. Large (1951) suggested the use of acetylene exploders for controlling avian pecan depredation because he found them successful in cherry orchards. Wilson (1974) found that acetylene exploders controlled crows best if reinforced with shooting. Dyer (1954) successfully frightened crows with rope firecrackers and shotgun patrols. Evers and Callahan (1954) found that amplified noises of dogs barking, people talking, cars honking and others scared crows out of an orchard. Wilson (1974), however, found recorded distress calls of crows ineffective.

Scarecrows have had little effect in controlling damage because birds habituate to them rapidly. Helium balloons (Larsen 1971) and hawk kites (Hothem 1982), however, have been used in cherry orchards and grape vineyards, respectively, with some success, and may provide the same protection for pecans.

Chemical repellents. The only repellent thus far studied and registered for pecan use is Avitrol (Avitrol Corp.) which is a chemical frightening agent. It causes birds to go into convulsions, emit distress calls, fly spirally (tower) and eventually die, all a short time after ingestion. The affected birds generally scare other birds away. Wilson (1974) found that for crow control, Avitrol provided the best seasonal protection of pecans in Louisiana. Other repellents such

as Hinder and methiocarb are available, and either have not been used or are not registered for use in pecan orchards.

Fencing. Electric or mesh fencing can be used to keep deer and rabbits (Sylvilagus spp.) from newly planted pecan seedlings. Aluminum girders stop squirrel depredation if limbs are not low to the ground, and adjacent trees are not close to the pecans. These techniques are used primarily for small scale operations.

Indirect control

Indirect control methods are designed to make other habitats more suitable or pecan orchards less desirable for depredators. These methods are not effective for all depredators.

Habitat manipulation. Many changes can be made in a pecan orchard or surrounding habitat to minimize damage. Sod should be established in orchards to provide less cover for wildlife. It should be mowed close to discourage rodent use. Trees and bushes of surrounding woodlands should be cut away from orchards to reduce cover (Carlton 1975). Nest trees used by squirrels can be cut down. Predators should be encouraged in the area, ie. roost poles can be set up for hawks. Seedlings should be planted when natural vegetation is available (Jaynes 1979). Growers could increase acorn production by thinning oak stands, which would alleviate some depredation. Most of these techniques are considered good management practices.

Early harvest. Growers should harvest pecans as early as possible. Many cultivars can be harvested earlier than most natives. Immediate harvest following ripening in native pecans, however, causes internal

cambium damage to trees. Batcheller et al. (1984) suggested an early harvest for native pecans. Conventional shakers would have to be changed to the type cherry growers use to prevent cambium damage, and portable pecan dryers similar to those used by peanut farmers would be needed to dry pecans immediately following harvest to prevent discoloration. This would be the best method of control as it would remove pecans before much damage occurred. Changing from conventional methods, however, would involve much time and money.

Blue Jay Damage

Blue jays are considered the major pecan depredator in Oklahoma. Control methods available for jays are ineffective. Two studies in central Oklahoma confirmed this. Leppla (1980) quantified damage from all vertebrate species and Batcheller (1980) described the ecology and behavior of blue jays in pecan orchards.

Leppla (1980) first noted blue jays in pecan orchards in late August and observed them taking pecans from ripening until harvest. Batcheller (1980) found that the population peaked in early October at about 4 jays/ha, coinciding with migrational movements. Most pecan damage occurred the first 2 weeks following ripening, approximately 1-14 October. Jays typically foraged in high nut production areas, but there was no relationship between distance to vegetative edge and number of jays using an area. Jays consumed pecans immediately or removed them to caches. Leppla (1980) determined that caching loss reached a maximum in late October and early November, but considered these losses insignificant in terms of total production. Batcheller (1980) recorded the most common group size for jays as 1 (71% of observations). Data

from these studies indicate that the control techniques used should be most intense for 2 weeks following the ripening of pecans and should be designed primarily for non-flocking birds.

Conclusion

Wildlife definitely have an impact on pecan production. Growers can experiment with different control techniques to determine which is most cost-effective. The control techniques used should be directed at the prominent depredators. In Oklahoma, blue jays are a serious depredator, yet little can be done to alleviate the problem. Shooting in conjunction with sound-scare devices probably works best.

Literature Cited

Batcheller, G. R. 1980. The ecology and behavior of blue jays in Oklahoma. M. S. thesis, Okla. State Univ., Stillwater. 45 pp.

Batcheller, G. R., J. A. Bissonette and M. W. Smith. 1984. Towards reducing pecan losses to blue jays in Oklahoma. Wildl. Soc. Bull. 12:51-55.

Boulvell, J. L. 1979. Economic considerations in pecan pest management. SE Pecan Grower Assoc. Proc. 72:55-59.

Carlton, R. L. 1975. Birds and animal damage control in pecans. Pecan South 2:5, 214-216.

Couch, G., G. Hedger, J. Watson and B. Peterson. 1977. Wildlife control panel. Okla. Pecan Growers Assoc. Proc. 47:39-46.

Dyer, R. 1954. Controlling crows with rope and firecrackers. Okla. Pecan Growers Assoc. Proc. 24:3-6.

Evers, W. T. and F. Callahan. 1954. Controlling crows with loud

speakers. Okla. Pecan Growers Assoc. Proc. 24:6-9.

Hothem, R. L. 1982. Raptor-mimicking kites for reducing bird damage to wine grapes. Proc. Vertebr. Pest Conf. 10:171-178.

Jaynes, R. A. 1979. Nut tree culture in North America. Northern Nut Growers Assoc., Inc. 466 pp.

Kennamer, E. F. 1959. Best methods of controlling crows and other pests in pecans. SE Pecan Growers Assoc. Proc. 52:32-35.

Kenworthy, E. 1954. Controlling crows by shooting from blinds. Okla. Pecan Growers Assoc. Proc. 24:1-3.

Large, J. R. 1951. The use of the "Salesco" carbide gun to protect pecan orchards from crow damage. SE Pecan Growers Assoc. Proc. 44:61-62.

Larsen, K. H. 1971. Bird control in orchards. Proc. Ore. Hort. Soc. 62:64-68.

Leppla, R. R. 1980. An assessment of damage to pecans by wildlife in central Oklahoma. M. S. thesis, Okla. State Univ., Stillwater. 71pp.

Livingston, R. L. 1973. Pecans in Georgia. Coop. Ext. Serv., Univ. Georgia, Athens. Bull. 609. 23pp.

Martin, A. C., H. S. Zim and A. L. Nelson. 1951. American wildlife and plants. McGraw-Hill Book Co., New York. 500pp.

Murray, M. L. 1975. An assessment of damage to Louisiana pecan orchards by the common crow (Corvus brachyrhynchos). M. S. thesis, Louisiana State Univ., Baton Rouge. 46pp.

Reed, D. 1973. Trapping squirrels. Okla. Pecan Growers Assoc. Proc. 43:29.

Shafer, C. E. and B. H. Bailey. 1978. Projected pecan production.

Pecan Quarterly 12:9-10.

Strother, G. R. and J. McVay. 1978. Pecan pest management. SE Pecan Growers Assoc. Proc. 71:85-89.

Wilson, R. C. 1974. An assessment of crow control techniques in pecan orchards of Louisiana. M. S. thesis, Louisiana State Univ., Baton Rouge. 83pp.

Woodbury, C. J. 1961. Local control of crows by trapping. J. Agric. W. Australia 2:33-35.

Woodroof, J. C. 1979. Tree nuts: production, processing, products. AVI Publ. Co., Inc., Westport, Conn. 731pp.

CHAPTER III

HINDER AS A WILDLIFE REPELLENT IN PECAN ORCHARDS

Investigator: Thomas C. Hall

Subject: Acute Oral LD50 and R50 in Birds

Test Material: Hinder (Thompson-Hayward Chemical Company)

Date: May 25, 1981

Introduction

Hinder, a proprietary product of the Thompson-Hayward Chemical Company which contains 15% ammonium soaps of higher fatty acids, was tested as a possible repellent for reducing animal damage in pecan orchards. It has been used with success in California orchards of various crops to repel mammals (Bowyer et al. 1977). Since birds are major depredators of pecans, this study was conducted to determine laboratory effects of Hinder as a bird repellent. Both toxicity (acute oral LD50) and repellency (R50) values were determined for Hinder and are discussed separately.

Acute Oral LD50 of Hinder

Methods

The experimental toxicity determination was based on acute oral LD50 test methods used at the Denver Wildlife Research Center, Colorado

(DWRC). Using this method, 2 birds are orally dosed with a chemical or formulated product at different treatment levels. Initial dosage is 2 g/kg body weight and treatment continues below this level until mortality ceases. LD50s are not determined above 2 g/kg since birds cannot hold a greater volume of liquid in their gastrointestinal tract.

Test birds were fasted for 2 hours prior to dosing. Hinder was administered orally using a 1 cc tuberculine syringe attached to an 18 gauge hypodermic needle with 3 cm of plastic tubing. Each bird was housed in a suspended, wire bottomed (1.2cm mesh), stainless steel cage. Test birds were observed continuously for 2 hours, and at 3 and 6 hours after treatment, and once daily for 7 days thereafter. Physical and behavioral abnormalities or mortalities were recorded. Body weights were recorded at the start and finish of the test. Examinations for gross pathological changes were conducted following mortalities and at the completion of the test on 1 bird from each dosage level. During the test, windows provided normal light-dark cycles (May) and temperature remained at 70 $\pm$ 2° F.

Results

Hinder was administered orally to 2 starlings (Sturnus vulgaris), 2 red-winged blackbirds (Agelaius phoeniceus) and 2 Japanese quail (Coturnix japonica) at a maximum level of 2 g/kg body weight (Table 1). All birds appeared normal following treatment except for red-winged blackbirds which vocalized abnormally for 2 hours. No mortalities occurred and a necropsied starling revealed no gross pathological changes. The LD50 for Hinder was concluded to be greater than 2 g/kg (>300mg/kg based on active ingredients).

R50 of Hinder

Methods

Experimental repellency determinations were based on R50 test methods used at DWRC. Using this method, 5 red-winged blackbirds are each offered 25 rice seeds treated with a specific concentration of a chemical or formulated product. The initial concentration used is normally 1% and treatment continues below this level until no repellency is observed. Values above 1% are not determined since previous experience has shown that chemicals active at these levels do not possess sufficient repellent activity for field use.

Birds were held in the laboratory for 2 days prior to the test and fed only rice. They were then subjected to a pretest phase where they were placed in individual, copper screen bottomed (160mm mesh for seed retainment) cages with 25 untreated rice seeds in an aluminum cup. Only those birds which consumed all 25 seeds in an 18 hour period were used for the R50.

Hinder was applied to rice seeds at 6.67% (1.00% active ingredients) and at 1.00% concentrations. Acetone was used with the undiluted formulated product to coat seeds evenly. Acetone was evaporated before seeds were tested. Five red-winged blackbirds at both concentration levels were placed in the same pretest cages for 18 hours with 25 treated rice seeds. Seeds were counted at the conclusion of the test. Criteria used for repellency was less than 13 rice seeds consumed.

Results

Ten red-winged blackbirds were used in the R50 study. Five birds were offered seeds treated with 6.67% Hinder (1% active ingredients) and 5 at the 1.00% level. The R50 value for Hinder was determined to be greater than 6.67% (>1.00% based on active ingredients) because birds ate all treated seeds in both tests.

Discussion

Laboratory tests indicate that Hinder is not a bird repellent at the levels tested. Field tests, however, are needed to verify this lack of activity. Because pecan orchards can suffer extreme losses to tree squirrels (Sciurus spp.), and because Hinder is known to repel mammals and is relatively inexpensive, field tests should be conducted to determine its effectiveness as a squirrel repellent in pecan orchards.

Field tests with Hinder should be conducted in August and September when 75-85% of squirrel damage occurs (Hall and Smith 1984). This would be an advantageous application time because the shucks have not dehisced which would make coating easier with a repellent.

Literature Cited

Bowyer, A. M., G. B. Hinckley and J. E. Davis. 1977. Protection of horticultural growth. U. S. Pat. 4,038,385. July 26.

Hall, T. C. and M. W. Smith. 1984. Wildlife damage ecology in pecan orchards. Pp. 38-69 in T. Hall. Wildlife damage and control in Oklahoma pecan orchards. M. S. thesis, Okla. State Univ., Stillwater. 69pp.

Table I. Toxicity (oral LD50) of Hinder for three bird species at a dosage level of 2 g/kg.

Species	Sex	Init. Wt.(g)	Final Wt.(g)	Dose (µl)	Behavioral Effects (Hours) 0-2	3	6	(Days) 1-7	Oral LD50
Starling	M	88	87	176	N[1]	N	N	N	>2g/kg
Starling	F	84	84	168	N	N	N	N	>2g/kg
Red-wing	M	68	67	136	A[2]	N	N	N	>2g/kg
Red-wing	M	67	67	134	A	N	N	N	>2g/kg
Coturnix	F	189	191	378	N	N	N	N	>2g/kg
Coturnix	F	149	151	298	N	N	N	N	>2g/kg

[1]normal

[2]abnormal

CHAPTER IV

EVALUATION OF TWO WILDLIFE CONTROL TECHNIQUES IN OKLAHOMA PECAN ORCHARDS

THOMAS C. HALL, Oklahoma Cooperative Wildlife Research Unit[1], Oklahoma State University, Stillwater, OK 74078

MICHAEL W. SMITH, Department of Horticulture and Landscape Architecture, Oklahoma State University, Stillwater, OK 74078

Abstract: Sound-scare devices and an application of methiocarb were evaluated as wildlife damage control techniques in Oklahoma pecan orchards in 1981 and 1982. Damage was assessed from ground plots. Caching loss was measured primarily for blue jays with flight-line counts. Neither method was statistically an effective treatment ($p>.10$). Sound-scare devices should be evaluated further because it may provide cost-effective protection in high damage level years. The best wildlife damage control techniques for native pecan orchards are 1) annual squirrel control with leg-hold traps and shooting, and 2) avian control during years when high damage levels are expected with sound-scare devices.

---

[1]Oklahoma Department of Wildlife Conservation, Oklahoma State University, U. S. Fish and Wildlife Service, and Wildlife Management Institute cooperating.

J. WILDL. MANAGE.

Key words: depredation, pecan, wildlife control, sound-scare devices, methiocarb, blue jay, squirrel, woodpecker

---

Pecan growers need efficient animal damage control techniques to curb wildlife depredation. Growers have tried many control techniques, but few have been adequately evaluated. Avitrol controlled damage from common crows (Corvus brachyrhynchos) in Louisiana orchards (Wilson 1974). Other control techniques which may be successful are sound-scare devices combined with shooting for crow control (Wilson 1974) and leg-hold traps for squirrel (Sciurus spp.) control (Reed 1973). Of the major pecan depredators, effective control has not been found for blue jays (Cyanocitta cristata).

Because blue jays are a major pecan depredator and available control techniques are ineffective, a 3-part project was initiated at Oklahoma State University. The first 2 studies were designed to 1) determine the amount of damage from blue jays as well as other wildlife in native pecan orchards (Leppla 1980), and 2) describe the ecology and behavior of blue jays in pecan orchards (Batcheller 1980). These studies were conducted to provide baseline data for this study, the third segment of the project.

Two control techniques were tested in this study in native pecan orchards of Oklahoma: 1) control with sound-scare devices, and 2) the application of methiocarb (4-(methylthio)-3,5 xyxyl N-methylcarbamate). These techniques were selected after a thourough review of available animal damage control techniques. Native pecan (seedling) orchards were selected because blue jay depredation is greatest in these orchards.

Crow depredation is most significant in cultivar (papershell) orchards. Blue jays were the primary target species for control, but other wildlife species were also considered in this study.

Sound-scare devices have been used extensively to control wildlife in pecan orchards. These, however, have had little success on blue jay depredation possibly because a limited number of devices was used or a sporadic shooting program was followed. Batcheller (1980) suggested intensive control with sound-scare devices for 2 weeks following the ripening of pecans to alleviate blue jay depredation. This is when he found the greatest population of jays in the orchard at approximately 4 jays/ha.

Methiocarb (Mesurol) has been used in agriculture as an insecticide, moluscicide and avian repellent. Previous studies found methiocarb to have high efficacy for reducing bird damage to sprouting seeds, ripening grains and fruits (Crase and DeHaven 1976). Methiocarb's primary mode of action is an illness-induced aversion (Rogers 1974). In Georgia, jay and crow activity appeared to decrease in cultivar orchards after Mesurol 75% wettable powder was applied at 1.68 kg/ha for insecticidal purposes (Nash 1978). Because methiocarb has high efficacy for reducing bird damage for many crops and because it seemed to work in Georgia orchards, it was tested as a control technique.

We acknowledge the Oklahoma State University Department of Horticulture and Landscape Architecture, Agricultural Experiment Station and the Oklahoma Cooperative Wildlife Research Unit for funding this project. We thank landowners R. Mount, and B. and S. Landgraf for use of their orchards. Also, we are grateful to F. Schitoskey, L. Talent,

D. Otis, W. Warde, E. Shafer, E. Stewart, and many others for their assistance in this study.

Study Areas

Study areas were located in eastern and southern Oklahoma in Okmulgee and Marshall counties. The Okmulgee County orchard was 9 km southwest of Beggs. The Marshall County orchards were 6 and 12 km west of Madill. These orchards consisted of native pecan trees with a few interspersed cultivars. Pecans began ripening (shuck-split) in late September and continued until early November. These sites were selected because both areas had a history of blue jay depredation, and because growers agreed not to implement wildlife control for the duration of the study. Test fields were selected at each site, but located far enough apart to minimize carry-over affects. Variability due to geographic location and management practices was eliminated because orchards were in the same locale and management practices were the same at each site. Cattle grazed orchards until mid-October, and growers had disease and insect control programs.

The sound-scare devices study was conducted in the Okmulgee County orchard. The orchard was about 200 ha located in the Deep Fork River floodplain. Four test fields, 8.17, 5.54, 10.00 and 11.82 ha with 355, 255, 447 and 612 trees, respectively, were selected within the orchard. Fields were all at least 1 km apart. Two test fields were treated with sound-scare devices and 2 were controls which received no treatment. The 4 fields were paired and 2 were randomly selected to receive treatment. Surrounding habitats included: oak (Quercus spp.) uplands dominated by several oaks, elms (Ulmus spp.) and honeylocust (Gleditsia

triocanthos); riparian woodlands dominated by sycamore (Platanus occidentalis), river birch (Betula nigra) and dogwoods (Cornus spp.); and bottomlands dominated by hickories (Carya spp.), elms, persimmon (Diospyros virginiana) and black willow (Salix nigra).

Methiocarb was applied in 2 Marshall County orchards, Site 1 was 20 ha and Site 2 was 14 ha, which were 7 km apart. Four test fields were located at Site 1, 0.36, 0.24, 0.53 and 0.53 ha with 19, 10, 12 and 21 trees, respectively. This area was located on an intermittent stream dominated by elms and sycamore, and adjacent to pasture with oak uplands nearby. Site 2 had 2 test fields, 1.28 ha with 38 trees and 3.06 ha with 93 trees. This area was surrounded by pasture with oak uplands a short distance away. A few cultivars bordered native trees at both sites. The 6 fields were paired by damage history, then 3 were randomly chosen to receive treatment of methiocarb and the other 3 were controls.

Methods

This study evaluated the effects of 2 control techniques, control with sound-scare devices and the application of methiocarb, on pecan depredation by blue jays and other wildlife. The 2 techniques were implemented differently, but sample methods were the same.

The sound-scare devices study was conducted from mid-September to November in 1981 and 1982. Acetylene exploders ("Zon Mark 2" scarecrow gun, B. M. Lawrence and Co., CA) were placed in every 4 ha of orchard. The number of blasts varied daily between 1/2.5-1/30 minutes. Exploders were faced different directions daily so birds would not habituate to their location as rapidly. Exploders had to be fenced so cattle would

not interfere with them. Coupled with the exploders, fields were patrolled with 12 gauge shotguns October 1-15 and sporadically thereafter until bird activity was negligible. Patrollers began by sunrise and continued until jay activity ceased which normally was before 1300 CST. Gizzard and crop contents from species collected in the field were visually examined for gross analyses of their diets.

In 1981, fields were patrolled October 1-14, and then sporadically until October 19. In field 1, 18 hours were spent patrolling with 2 exploders in use for 99 hours using 5.6 kg of propane. Patrollers fired 78 shotgun shells. Total cost was $19.14/ha. In field 2, 27 hours were spent patrolling with 3 exploders in use for 99 hours using 7.7 kg of propane. A total of 122 shotgun shells were fired. Cost in this field was $15.07/ha. Average cost of control was $17.11/ha. The 1981 and 1982 costs of control were calculated with patrol costs of $3.50/hr, 12 gauge shotgun shells at $4.50/box and propane at $.33/kg. The cost of cannons ($200.00) was prorated over a 10 year period and in a 4 ha orchard cost $5.00/ha to use.

In 1982, fields were patrolled October 1-15, and then sporadically until October 26. In field 1, 44 hours were spent patrolling, 2 cannons were used for 159 hours and burned 10.9 kg of propane. Patrollers fired 148 shotgun shells. Control cost $38.06/ha. In field 2, 82 hours were spent patrolling, and 3 cannons used 15.1 kg of propane in 159 hours. Patrollers fired 260 shells. Cost of control was $33.66/ha for this field. Average cost of control for 1982 was $35.86/ha.

The methiocarb study was abandoned in 1981 because a flood covered plots with sand in late October, and little wildlife damage had occurred by this time. Blue jays damaged less than 0.1% of the crop. The study

was conducted from mid-September to November in 1982. Methiocarb was applied in 3 orchards of Marshall County at 1.9 kg/ha with local spray equipment. A surfactant was added to the methiocarb and water to help maintain an even solution. Methiocarb was applied at night on October 9 and 23, 1982 when prevailing conditions were good (no wind and no precipitation in forecast). Average cost of treatment for all fields was $138.05/ha. Dead bird transects (100m x 3m) were conducted weekly, but no birds were found. Non-target bird transects (100m x 20m) were also conducted weekly in each treated field. These were perpendicular to the orchard edge on a line 50 m in the orchard to 50 m into adjacent cover. Residue analyses were conducted on pecans and nutmeat after harvest to determine the % methiocarb. Analyses were conducted at the Denver Wildlife Research Center and found 0 ppm methiocarb on pecans at harvest.

Animal damage was assessed using ground plots under trees similar to Murray's (1975) technique. Two 1 m^2 plots were placed under 40 randomly selected trees in each of the 4 Okmulgee County fields, and in Marshall County, under all trees at Site 1 and under 30 trees in each of the 2 fields at Site 2. Plots were marked with shiners (5cm diameter metal discs) nailed into the ground. Shiners were placed 2 m away from the trunk at 45° and 225°, but always within $1\frac{1}{2}$ m of the canopy edge. Plots were sampled 5 times in 1981 and 4 times in 1982. Sampling began in late September and continued until harvest. A meter square frame was placed over the plot, and the plot was thouroughly searched for pecans or pieces. Nuts collected were recorded by length (<3.0cm, 3.0-3.5cm, 3.5-4.0cm, 4.0-4.5cm, >4.5cm or unknown), and as damaged or undamaged. Undamaged pecans were marked and returned to the plot in 1982. The

number of marked pecans remaining the following count was recorded. The difference from the previous count was used to determine ground removal rates. Damaged pecans were inspected to determine damage type: wildlife, abortion, insect, cow, mechanical or unknown. The source of wildlife damage was determined by type of entry. Avian species leave beak marks, grooves left where the beak strikes the pecan. Blue jays open pecans at the apical end and usually open a face; crows usually open an entire face by breaking a pecan into several pieces. Woodpeckers open a hole in the face of a pecan, sometimes breaking it into several small pieces. The top and bottom of the pecan can usually be found. Small birds, ie. titmice (Parus spp.), open a small hole on the face of thin-shelled pecans. Mammals either leave gnaw marks or crushed pieces with no beak marks. Squirrels leave large gnaw marks on broken pieces, or if early damage, a puncture hole in a nutlet. Cotton rats (Sigmidon hispidus), eastern woodrats (Neotoma floridana) and deer mice (Peromyscus maniculatis) open a pecan at either end. White-footed mice (P. leucopus) open the face of pecans. Other wildlife, ie. waterfowl and predators, eat pecans whole or crush them beyond recognition, so their damage cannot be measured. At harvest, pecans from each plot were weighed by size class for an estimate of overall production and damage. Diameter at breast height and canopy cover were measured for each tree. Canopy cover was used to determine the actual cover of trees in an orchard since plots were not randomly established throughout and were always under the canopy of trees.

Blue jay, crow and woodpecker caching loss was estimated using flight-line counts similar to Leppla's (1980). However, 2 plots were established, 1 randomly and the other on the opposite side of the field.

The per cent of the perimeter that was observed was recorded to determine kg/ha lost. Flight-line counts were 15 minutes long and were conducted from late September to harvest, 800-1100 CST.

Avian population levels were measured using time-area counts similar to Batcheller's (1980). Counts were conducted from late September to harvest. Censuses started at sunrise and were finished by 1100 CST. Five minute situating periods preceded 15 minute counts, and all species seen or heard were recorded as either flying over the plot or in it.

Results and Discussion

Control with sound-scare devices and the application of methiocarb were not effective treatments. Both treated and control fields sustained wildlife damage (Table 1), and differences were not statistically significant in T-tests. From observation, however, some success was evident in both treatments. In general, treated fields sustained less damage than did control fields, but differences could have been inherent in fields themselves. A larger field sample size was needed to more accurately determine the effects of treatments. Therefore, conclusive statements cannot be made without further research.

Pecan production and wildlife damage were significantly different between 1981 and 1982 in ANOVA tests ($p<.01$). Pecan production averaged 1135 kg/ha in control fields of Okmulgee County in 1981. In 1982, pecan production averaged 768 kg/ha. Wildlife damage from control fields in Okmulgee County was 31.5 kg/ha in 1981 and 153.4 kg/ha in 1982. Results were similar in Marshall County between years, but accurate data was

unavailable because the study was cancelled in 1981. Differences in wildlife damage were largely dependent on alternate food source availability, primarily insects and wild mast. Both insects and mast were abundant in 1981 coinciding with low damage levels. In 1982, insects and wild mast were low, and wildlife damage was high.

Squirrel and woodpecker damage accounted for much of the wildlife damage in 1981 (0.6% each). Squirrel damage was poorly measured at first because some of their damage types were unknown. Squirrel damage was probably higher by 1%. Therefore, in years of high wild mast production and high insect availability, the primary target species for control measures would be squirrels. Blue jays, squirrels and woodpeckers caused greatest damage in 1982 in control fields (13.9%, 7.2%, 3.3%, respectively). They are the target species of control during years of low mast and low insect availabilty. Crows are the major depredator and the target species of control in cultivar orchards (Murray 1975).

Treatment Evaluations

Sound-scare Devices

The sound-scare devices study was conducted in Okmulgee County in 1981 and 1982. Overall pecan losses were greater in control fields, but T-tests did not support a significant difference between treated and control fields for wildlife protection ($p>.10$) (Table 1). The only significant results from T-tests, testing the difference in estimated kg/ha of damage, were obtained in 1981 with blue jay control ($p<.025$) and in 1982 with woodpecker control ($p<.05$). These results may not have been caused by treatment because the difference of damage before and

after treatment in treated and control fields in T-tests was not significant ($p>.10$). The only control with sound-scare devices which may have been significant was that of blue jay control in 1982. Both the difference from before and after treatment, and the difference in kg/ha damage between control and treated fields had $p < .10$.

Bird census data supported the conclusion that treatment did not have an affect on population numbers (Table 2). No statistical differences in ANOVA tests between the population numbers of blue jays, crows or woodpeckers in control and treated fields were found ($p>.10$) in 1981 or 1982. The average number of birds were generally lower in treated fields which compared with damage results, but differences could have been inherent in fields themselves.

From general observations, sound-scare devices appeared to partially work. Acetylene exploders seemed effective for a few days, but birds habituated to them after 3-5 days of use. The cannons, combined with patrollers, made jays and crows wary when entering treated orchards. Birds would stop near the edge, scan for patrollers, and then enter. If a patroller was spotted, birds would usually slip away before the patroller had a chance to shoot. If an alarm call was given, jays would scatter to a safe distance (about 50m) to determine possibly why it was given, but crows would leave the area (>100m). Lower damage levels probably resulted because of the cautiousness and general lack of activity displayed by jays and crows.

Woodpeckers seemed unaffected by sound-scare devices. Patrollers were able to approach them much easier than other species (<50m). Woodpeckers would remain in their territories, especially red-headed woodpeckers (Melanerpes erythrocephalus), even if pursued by a

patroller. If shot, a woodpecker's territory would remain vacant for a day or longer. Damage levels may have been decreased in treated fields because of the lack of use of vacant territories.

Squirrels were very cautious throughout the orchard because of a long history of squirrel hunting. Patrollers had to be canny when hunting squirrels. When anyone was spotted within 200 m, they would immediately take to nearby den trees or lay low on high branches. Because activity levels were hampered by patrollers and because patrollers had an impact on squirrel populations, damage levels may have decreased due to treatment.

Control costs averaged $17.11/ha in 1981 and $35.86/ha in 1982. If the averages in Table 1 were true damage estimates, 9.2 kg/ha in 1981 and 44.6 kg/ha in 1982 were saved by treatment. The average wholesale price of pecans in 1981 was $1.00/kg and in 1982 was $1.40/kg. Control would have lost $9.03/ha in 1981. However, control would have saved $26.58/ha in 1982, and would have been cost-effective. Therefore, this technique would be most feasible to use during years of expected high damage: low pecan and wild mast production, and low insect availability.

Methiocarb

Methiocarb was applied in 3 orchards of Marshall County in 1982. This control method was not an effective treatment. T-tests did not support a significant difference between control and treated fields for wildlife protection ($p>.10$) (Table 1). Major differences between fields were inherent in Marshall County which confounded results. One treated field was almost completely depredated by squirrels prior to treatment,

and its pair control field was heavily depredated by blue jays before and after treatment.

Bird count data (Table 2) supported 1 significant difference in ANOVA tests for the difference in blue jay pressure between control and treated fields ($p=.0046$). This difference was countered by a non-significant ANOVA test for treatment by date ($p=.777$). This suggests that bird pressure was similar in all fields, but that blue jay numbers were consistantly greater in control fields. Differences were noted to be primarily due to field arrangement.

Methiocarb seemed effective for a short term after application, primarily for blue jays. Blue jays were foraging and caching in fields prior to the first treatment. Activity basically stopped in treated fields after the application of methiocarb. One jay entered a treated field, foraged for a pecan, became sick (bill wiping) and vocalized as it left the area. During observation, no other jays were seen in that orchard. After a few days, however, activity levels increased to normal. The second application seemed less effective as jays foraged equally before and after treatment. Woodpecker pressure seemed to decrease slightly after treatment.

Cultivar trees were monitored for crow depredation during the study. A group of cultivars was sprayed after heavy crow depredation. Treatment did not appear to affect the intensity of damage because crows foraged equally before and after treatment.

The cost of spraying methiocarb was $138.05/ha, and at best maybe 30 kg/ha was saved. Therefore, this method would not be considered cost effective because treatment would have lost $96.05/ha. The problem with this type of treatment is that not enough chemical is ingested by target

species because the pecan shell and shuck are not consumed. The reason jay activity may have decreased, was probably because enough methiocarb was on pecan shells that when jays cached pecans, the saliva in their mouths removed any methiocarb, making them sick.

Methiocarb possibly could be an effective treatment at different levels than those tested in this study. Cost-effective results, though, would be hard to obtain because of the high cost of spraying methiocarb. Because the application of such treatments is easy, another spray may be found through research which would be a cost-effective technique.

Conclusion

Sound-scare devices and the application of methiocarb were evaluated as wildlife damage control techniques in native pecan orchards in Oklahoma. Neither treatment was effective statistically. Some protection was noted with both techniques. Sound-scare devices, though, would be the only cost-effective technique, and only in years of high depredation levels.

Blue jays, squirrels and woodpeckers are the most significant depredators in native orchards. Squirrel damage is significant most years, but mainly in low mast production years. Many squirrels come from woodlands adjacent to orchards and depredate a large percentage of pecans on the perimeter during low mast production years.

Jay and woodpecker damage is most significant in years of low wild mast production and low insect availability. Jays are especially significant depredators because of the large percentage of pecans they cache. These birds primarily need to be controlled in low food availability years. Avian damage can be expected to be low (<2% for all

birds) during high food availability years, which would make the cost-effectiveness of control techniques less economical.

The best management plan for native orchards would be two-fold. First, since squirrels are a local population and damage can be significant annually, they should be controlled regularly. In our opinion, the best method for squirrel control is a combination of trapping and shooting. Size $1\frac{1}{2}$ leg-hold traps should be placed on 'L-shaped' 2"x 4"s nailed to the trunks of trees, 1-2 m above the ground (Reed 1973). These should be baited regularly with peanut butter, aluminum, etc. throughout the year, especially in spring when other foods are scarce. Shooting is best accomplished in late spring and summer when juveniles are not so wary; and at harvest squirrels can easily be shot because most come out of their dens when trees are shook.

A sound-scare device program should be conducted during years when high damage is expected for birds, primarily blue jays and woodpeckers. The program should be most intense during the last half of October. Cannons should be placed in every 5-10 ha of orchard and started by October 1. Cannons should be moved at 3-5 day intervals. Patrollers should shoot sporadically beginning October 5, and continue with growing intensity towards late October. Then periodic patrolling up until harvest is advisable. If animals are to be trapped or killed, permits must be obtained from the state for all species, and from the U. S. Fish and Wildlife Service for migratory species.

A good management practice would be to thin and maintain oaks around the perimeter of orchards to maximize acorn production. This would short-stop many species from entering the orchard and would

decrease damage levels significantly because wildlife, especially blue jays, seem to prefer acorns to pecans. Black oaks produce better yields annually than white oaks, and may be more beneficial to maintain (Sharp 1958).

Research Needs

Since pecan damage is a significant problem to growers, further research is needed to evaluate control techniques. Several methods exist which have not been evaluated or refined for cost-effectiveness. For example, a series of scarecrows and sound-scare devices might be used at 3-5 day intervals in conjunction with shotgun patrollers to alleviate damage. Also, new control techniques may become available which may be effective, and should be tested, ie. new chemical repellents.

Techniques to evaluate pecan damage would have to be refined for a better understanding of treatment effects. The sample size for treated and untreated fields should be a minimum of 3 pairs. The sample size within each field could also be increased. For animal damage control studies an ideal coefficient of variability is .15, which gives a standard deviation of $x \pm x(.15)$. From our tests, 40 trees with 2 plots measured production of pecans to $x \pm x(.154)$ which was acceptable. However, total wildlife damage was estimated to only $x \pm x(.202)$. This means that about 60 trees with 2 plots would measure wildlife damage to an accurate degree. Additional plots would be needed to measure individual species damage to a more accurate degree. Plot size could probably be reduced from the 1 m^2 used in this study.

Caching losses should be estimated with a better technique for

squirrels and woodpeckers. Flight-line counts should be conducted at frequent intervals. From our study, no correlation was found between caching loss of blue jays and damage on the ground, but possibly could be in future studies. Bird counts should be conducted as an indication of pressure, but are not necessary to determine the effects of treatment.

Literature Cited

Batcheller, G. R. 1980. The ecology and behavior of blue jays in Oklahoma. M. S. thesis, Okla. State Univ., Stillwater. 45pp.

Crase, F. T. and R. W. DeHaven. 1976. Methiocarb: its current status as a bird repellent. Proc. Vertebr. Pest Control Conf. 7:46-50.

Leppla, R. R. 1980. An assessment of damage to pecans by wildlife in central Oklahoma. M. S. thesis, Okla. State Univ., Stillwater. 71pp.

Murray, M. L. 1975. An assessment of damage to Louisiana pecan orchards by the common crow (Corvus brachyrhynchos). M. S. thesis, Louisiana State Univ., Baton Rouge. 46pp.

Nash, R. F. 1978. Update of activity of Mesurol in pecan orchards. SE Pecan Growers Assoc. Proc. 71:139-148.

Reed, D. 1973. Trapping squirrels. Okla. Pecan Growers Assoc. Proc. 43:29.

Rogers, J. G. 1974. Response of caged red-winged blackbirds to two types of repellents. J. Wildl. Manage. 38:418-423.

Sharp, W. M. 1958. Evaluating mast yields in the oaks. Agr. Exp. Sta., Penn. State Univ., University Park. Bull. 635. 22pp.

Wilson, R. C. 1974. An assessment of crow control techniques in pecan

orchards in Louisiana. M. S. thesis, Louisiana State Univ., Baton Rouge. 83pp.

Table 1. Estimated production and damage losses in pecan orchards for control with sound-scare devices in 1981 and 1982 in Okmulgee County (2 treated, 2 control fields) and with methiocarb in 1982 in Marshall County (3 treated, 3 control fields), and associated paired T-tests.

	Production Total	Undamaged Pecans	Wildlife Damage	Blue Jay Damage	Blue Jay Caching	Squirrel Damage	Woodpecker Damage
			OKMULGEE COUNTY 1981				
Control	1135 (154)[a]	869 (128)	31.5 (6.0)	1.21 (0.73)	0 -	6.42 (2.32)	7.32 (2.23)
Treated	1326 (170)	1087 (139)	22.3 (4.0)	0.71 (0.34)	0.20 -	4.28 (1.61)	3.28 (1.83)
T-value 1[b]	-2.70	-24.77	4.09	24.07[c]	-1.00	2.06	2.70
T-value 2[d]	-	-	2.01	1.70	-1.00	2.08	0.46
			OKMULGEE COUNTY 1982				
Control	768 (151)	413 (99)	153.4 (32.3)	18.93 (6.78)	11.80 -	64.21 (16.21)	23.07 (6.17)
Treated	735 (114)	460 (88)	108.8 (24.4)	7.59 (2.16)	3.82 -	49.54 (15.21)	13.02 (2.85)
T-value 1	0.20	-0.66	1.19	4.08	3.00	0.44	7.40[c]
T-value 2	-	-	1.15	4.02	3.00	-1.18	1.16
			MARSHALL COUNTY 1982				
Control	472 (115)	166 (51)	193.4 (48.4)	16.73 (6.22)	95.22 -	28.02 (12.71)	16.80 (5.07)
Treated	558 (220)	230 (137)	186.0 (75.7)	11.64 (7.47)	22.05 -	130.83 (64.80)	8.09 (3.47)
T-value 1	-1.24	-0.76	2.04	2.04	2.17	-1.27	1.10
T-value 2	-	-	1.89	2.33	1.98	1.22	6.27[c]

[a] standard error

[b] T-tests conducted for the difference in production or damage (kg/ha) between control and treated fields with 1 degree of freedom in Okmulgee County and 2 in Marshall County

[c] significant difference

[d] T-tests conducted for the difference in damage before and after treatment between control and treated fields with 1 degree of freedom in Okmulgee County and 2 in Marshall County

Table 2. Blue jay, crow, red-bellied woodpecker and red-headed woodpecker mean birds/ha estimated in time-area bird counts in pecan orchards for control with sound-scare devices in 1981 and 1982 in Okmulgee County, and with methiocarb in 1982 in Marshall County, Oklahoma, and associated ANOVA tests.

	n	Jay	Crow	R-bellied	R-headed
		OKMULGEE COUNTY 1981			
Control $\bar{X}$	14	1.58	0.73	0.32	0.93
Treated $\bar{X}$	14	1.33	0.28	0.44	1.21
P[a] (1 df)[b]		.831	.199	.678	.190
P[c] (4 df)		.477	.639	.738	.066
		OKMULGEE COUNTY 1982			
Control $\bar{X}$	12	3.21	2.41	1.13	0.38
Treated $\bar{X}$	12	1.74	0.80	0.99	0.52
P[a] (1 df)		.077	.186	.464	.399
P[c] (3 df)		.662	.910	.550	.538
		MARSHALL COUNTY 1982			
Control $\bar{X}$	21	6.14	0.27	1.02	0.05
Treated $\bar{X}$	21	3.07	0.59	0.78	0.03
P[a] (1 df)		.005[d]	.209	.243	.658
P[c] (6 df)		.777	.422	.976	.369

[a]ANOVA tests were conducted for the difference in average bird pressure between control and treated fields (P=probability)
[b]degrees of freedom
[c]ANOVA tests were conducted for the difference in bird pressure by date between control and treated fields (P=probability)
[d]significant difference

CHAPTER V

WILDLIFE DAMAGE ECOLOGY IN PECAN ORCHARDS

THOMAS C. HALL, Oklahoma Cooperative Wildlife Research Unit[1], Oklahoma State University, Stillwater, OK 74078

MICHAEL W. SMITH, Department of Horticulture and Landscape Architecture, Oklahoma State University, Stillwater, OK 74078

Abstract: Wildlife damage ecology was studied in Oklahoma native pecan orchards in 1981 and 1982. Twenty-eight species depredated pecans of 106 identified as potential pecan pests in the United States. Twelve species were considered secondary consumers (ate damaged pecans). In 1981, pecan production was high, and wildlife damage was only 2% or 22.5 kg/ha. In 1982, pecan production was low, and wildlife damage was 30% or 173.4 kg/ha. Insect and wild mast availability were major factors contributing to changes in wildlife damage. Population numbers of different species did not always correspond to damage levels. Blue jays (Cyanocitta cristata), squirrels (Sciurus spp.) and woodpeckers (Melanerpes spp.) caused 75-85% of the wildlife damage. Blue jays, squirrels and woodpeckers damaged 0.1%, 0.6% and 0.6% of the total pecan crop in 1981 and 13.9%, 7.2% and 3.3% in 1982, respectively. Pecan size

---

[1]Oklahoma Department of Wildlife Conservation, Oklahoma State University, U. S. Fish and Wildlife Service, and Wildlife Management Institute cooperating.

influenced damage levels for several species: jays, squirrels and woodpeckers prefer small pecans (<4.0cm) whereas crows prefer large pecans (>4.0cm). Only 5% of pecans sampled were > 4.0 cm, hence damage was light for crows. Data for several other species is discussed. The best control method for most species in native orchards is shooting in conjunction with sound-scare devices, and in cultivar orchards, is Avitrol combined with shooting and an early harvest regime.

J. WILDL. MANAGE.

Key words: depredation, pecan, control, blue jay, Cyanocitta cristata, squirrel, Sciurus spp., woodpecker, crow, damage ecology

---

Wildlife depredation to pecans in the United States is a significant problem. The United States produces over 90 million kilograms of pecans annually (Shafer and Bailey 1978). We estimate that wildlife damage at least 10% of the total pecan crop; at 1982 prices this represents a 21 million dollar annual loss to growers. As more land is developed into pecan orchards, the problem will increase. Even though this can be considered a major agricultural problem, not much is known about the depredators because little research has been conducted in this area.

Pecan production is divided into 2 categories: natives (seedlings) and cultivars (papershells). Natives are primarily depredated by blue jays (Scientific names given in Table 1), fox squirrels and woodpeckers. Cultivars, however, are most heavily depredated by common crows (Murray 1975). Of these, blue jays, crows and squirrels are considered the major depredators in the United States (Livingston 1973, Carlton 1975). A total of 106 species have been identified as possible pecan pests: 31

are known depredators, 68 are possible depredators and 7 disturb orchard maintenance (Table 1). Also, 12 species have been identified as secondary consumers of pecans (consume damaged pecans).

We conducted a study in Oklahoma pecan orchards to determine the effectiveness of different wildlife damage control techniques (Hall and Smith 1984). During this study, much was learned about wildlife damage ecology. This paper will discuss the species found causing damage and pertinent data about them.

We acknowledge the Oklahoma State University Department of Horticulture and Landscape Architecture, Agricultural Experiment Station, and the Oklahoma Cooperative Wildlife Research Unit for funding this project. We thank landowners R. Mount, and B. and S. Landgraf for use of their orchards. We are also grateful to F. Schitoskey, L. Talent, D. Otis, R. McNew, J. Guarino, E. Stewart and many others for their input into this study.

Study Areas

Study areas were located in eastern and southern Oklahoma in Okmulgee and Marshall counties. These orchards consisted of native pecan trees with a few interspersed cultivars. Pecans began ripening in late September (Sept. 25, 1981 and Sept. 27, 1982) and continued until harvest, which was initiated in early November. These sites were selected because both areas had prior histories of wildlife depredation and because growers agreed not to implement wildlife control for the duration of the study. At both sites, cattle were allowed to graze until mid-October, and growers had insect and disease spray programs.

The Okmulgee County orchard was 200 ha located in the Deep Fork

River floodplain. Two test fields, 8.2 ha with 355 trees and 10.0 ha with 447 trees, were selected from within the orchard. The fields were approximately 1.5 km apart. Adjacent habitats included oak (Quercus spp.) uplands, riparian woodlands and willow (Salix spp.) bottomlands.

Two orchards approximately 6.4 km apart were used in Marshall County. Site 1 was a 20 ha orchard located on an intermittant stream, and adjacent to oak uplands and pastures. Two fields, 0.4 ha and 0.5 ha with 19 and 12 trees, respectively, were selected within the orchard. Site 2, a 14 ha orchard, had 1 test field which was 1.3 ha with 38 trees. Site 2 was surrounded by pastures with oak uplands nearby.

Methods

Animal damage was assessed using ground plots under trees similar to techniques used by Murray (1975). Two 1 m^2 plots were placed under 40 randomly selected trees in each field in Okmulgee County, and under all trees at Site 1 and under 30 trees at Site 2 in Marshall County. Plots were marked with shiners (5cm diameter metal discs) nailed into the ground. A m^2 frame was placed on the shiner, and each plot was thouroughly searched for pecans or pieces. Shiners had right angles marked on them, so the same plot was sampled. Plots were placed 2 m southwest and northeast of the trunks of trees, but always within $1^1/_2$ m of the canopy edge. Plots were sampled 5 times in 1981 and 4 times in 1982, beginning late September and continuing to harvest. Nuts collected were recorded by length (<3.0cm, 3.0-3.5cm, 3.5-4.0cm, 4.0-4.5cm, >4.5cm or unknown), and as damaged or undamaged. In 1982, undamaged pecans were marked and returned to the plot. The number of marked pecans found in the following count was recorded. The difference

from the previous count was used to determine ground removal rates. Damaged pecans were inspected to determine damage type: wildlife, abortion, insect, cow, mechanical or unknown. The source of wildlife damage was determined by type of entry. At harvest, undamaged pecans from each plot were weighed by size class. Weights from each size class were then averaged for each area and year for use in estimating damage losses and total production.

Canopy cover, diameter at breast height and height were measured for each tree. Average canopy cover was multiplied by the number of trees in test fields to determine actual coverage of trees in that field because plots were not randomly established throughout the orchard and were always under tree canopies. Diameter at breast height and height of tree were recorded to determine if differential blue jay damage occurred due to these variables.

Blue jay, crow and woodpecker caching losses were estimated using flight-line counts similar to Leppla's (1980). In this study, however, 2 plots were established, 1 was randomly selected and the other was established on the opposite side of the field. The per cent of perimeter observed from the 2 plots was determined. Flight-line counts were 15 minutes long, and were conducted between 800-1200 CST from late September until harvest. Approximately 5 hours of active caching took place from 800-1300 CST, and about 1 in 3 jays would carry more than 1 pecan. Blue jays usually cached small pecans (>3.0cm). Loss was then calculated from these factors.

Avian population levels were calculated using time-area counts similar to the method used by Batcheller (1980). Counts were conducted from late September to harvest. Censuses were conducted from sunrise to

1100 CST. Five minute situating periods preceded 15 minute counts, and all species seen or heard were recorded as flying over or in the plot.

Results and Discussion

Pecan production between 1981 and 1982 was significantly different ($p<.01$). Pecan production in 1981 averaged 1244 kg/ha (Table 2). Of the total production, 74% was harvestable. Normal orchard loss (abortions, insect, cow and mechanical damage) accounted for 24% of the damage. Abortions comprised of about half of the damage, and insects accounted for much of the remaining damage. Mechanical and cow damage were relatively insignificant. Lastly, wildlife damaged an average of only 2% of the crop in all study fields in 1981.

Production decreased to about 620 kg/ha, and wildlife damage increased significantly in 1982. Normal orchard loss remained relatively constant at both sites, 26% in Okmulgee County and 24% in Marshall County. In Okmulgee County, wildlife damage was 20%, and 54% of the total production was harvested. In Marshall County, wildlife damage was 41%, and only 35% of the crop was undamaged. These figures represent a substantial reduction from the potential harvest.

Blue jays, squirrels and woodpeckers account for 75-85% of the wildlife damage in a native pecan orchard. Thus, these species are of most concern to native growers, whereas crows are the primary concern of cultivar growers. The data gathered for these species will be discussed along with mention of other depredators. Not all species from Table 1 will be discussed because little information is available for them, especially in the west where pecans are a relatively new crop.

Blue Jays

Blue jays are the most serious depredator of native pecans. This is partially due to the large number of pecans they cache. Blue jays seem to favor acorns and insects, and jay damage to pecans is largely influenced by alternate food source availability. Most researchers have suggested that blue jay damage is inversely proportional to acorn production (Couch et al. 1977, Leppla 1980). We found this to be true between 1981 and 1982. In 1981, acorn production was high and jay damage was light, whereas in 1982, acorn production was low and jay damage was high. Although acorn production was high in 1981, acorns were not the major part of the jay's diet. Acorns were more notably cached. Insect and acorn availability were only grossly observed in this study. These should be monitored in future research.

Esophageal and gizzard contents of 44 jays in 1981 and 84 jays in 1982 were grossly examined in the field. Insects were the major food item encountered in jays' diets in October when little damage occurred. Insects were very abundant in and around the orchard. But, as cold weather came and insects became unavailable, pecan damage increased along with the consumption of nutmeats by jays. In 1982, insects were scarce in the orchard. Some insects were part of the diet in early October, but not with the frequency as 1981.

Blue jays generally open a face of a pecan by hammering at the apical end where groove marks are left (figure 1). The top of the pecan may be broken into several pieces leaving only the bottom half. Cached pecans are removed whole, and flight-line counts accounted for this damage. Blue jays favor small pecans to larger ones which reflects their ability to handle them. Of the pecans in a native pecan orchard,

they damage pecans under 4.0 cm with equal frequency as they are found in the orchard (Table 3).

Blue jay damage varied greatly between 1981 and 1982 (Table 2). Jays damaged 1.2 kg/ha or 0.1% of the total production in 1981. In 1982, damage increased to 71.0 kg/ha representing 13.9% of production. Caching was responsible for no loss in 1981 and for 53.2 kg/ha in 1982. Leppla (1980) found that caching was an insignificant loss in 1979 in orchards of central Oklahoma. His caching estimates were 3.17 kg/ha. In cultivar orchards of Louisiana, blue jays damaged 0.46% of the total pecan crop (Murray 1975). These findings suggest that damage differs from area to area and year to year, and that a greater percentage of damage occurs in native orchards which reflects their tendency to depredate smaller pecans.

Caching represents a major segment of blue jay damage. Jays seem to have a symbiotic relationship with nut trees. In Virginia, jays cached 133,000 acorns and consumed 49,000 from an 11 tree pin oak (Quercus palustris) stand representing 74% of the total mast crop (Darley-Hill and Johnson 1981). Caching represented 73% of their damage. In 1981 and 1982, acorns were cached heavily until the source was depleted; then jay damage and caching increased in orchards. Cached pecans represented 74% of jay damage in this study in 1982. Caching and damage may have increased if acorns were unavailable, especially at the Okmulgee County site. Cached nuts are probably not retrieved often as nuts are covered with debris or hammered into ground, and usually more than a meter apart (Darley-Hill and Johnson 1981). Four caches were observed in this study: 1 on an open hillside, 2 in pastures and 1 in an oak woodland. Darley-Hill and Johnson (1981) noted that 91% of

cachings were in lawns or on bare soil in areas conducive for seed germination. This behavior of jays makes control much more difficult.

Blue jay damage chronology (figure 2) was similar at both orchards. Damage was very light in 1981, and reached a maximum in late October. Damage was high in 1982, starting about October 1 and reaching a maximum in early November.

Blue jay populations in orchards (figure 3) did not always correspond to damage levels. Even though blue jays were in and around the orchard, they were not damaging pecans, especially when other foods were available. Counts indicated that 1.58 jays/ha in 1981 and 4.68 jays/ha in 1982 were the average number of jays found in orchards from late September to early November. Populations peaked in mid-October, 1981 at 3.58 jays/ha, and in late October, 1982 at 7.54 jays/ha. Damage levels corresponded with population numbers in 1982, but did not in 1981. Batcheller (1980) found that populations peaked at 4.53 jays/ha and 3.40 jays/ha in mid and early October of 1978 and 1979, respectively. He concluded that most damage occurred then.

Jays collected in 1981 were aged (HY=hatching year, AHY=after hatching year) and sexed internally (Norris 1961, Lamb et al. 1978). Of 44 jays, there were 10 AHY males, 7 HY males, 15 AHY females and 12 HY females. Batcheller (1980) found a predominance of AHY males in orchards. He suggested that possibly this was due to differential mortality of females at nesting, differential vulnerability to shooting by AHY males, or subadult suppression in orchards. We suggest that possibly differential migration occurs between AHY females and young, and AHY males rather than for reasons suggested by Batcheller (1980).

Diameter at breast height (DBH) and height (ht) of tree were

suggested by Batcheller (1980) to affect damage. He found that most jay activity occurred in larger than average DBH trees and consumption took place in shorter than average trees. We found in the Okmulgee County orchards which had a diversity of trees that consumption activities increased with increasing DBH and ht (Table 4). However, many of the smaller trees in the Okmulgee orchards were those of cultivars with large nuts which few jays depredate. Therefore, DBH and ht may not be a factor in determining damage levels. Combined with Batcheller's (1980) findings, we suggest that pecans are chosen in trees with preferred nuts and consumed in trees with branches suitable for hammering open a pecan.

Blue jay control has been difficult for growers. The best method would be the use of sound-scare devices during years blue jay damage is expected to be high (Hall and Smith 1984). Because acorn production is crucial to damage intensity in pecans, increasing acorn production by thinning oak stands adjacent to orchards for higher production levels would be a good management practice (Batcheller 1980).

Squirrels

Two species of squirrels depredate pecans, eastern fox and eastern gray squirrels. Fox squirrels depredate more pecans than gray squirrels because they occur at greater frequencies in orchards. Fox squirrels prefer open woodlands, whereas gray squirrels prefer dense woodlands which can be found adjacent to orchards (Smith and Follmer 1972). Most gray squirrel damage occurs along the perimeter of orchards. Because damage by these species is indistinguishable, data gathered for them is combined. Southern flying squirrels were also in study areas and

possibly did some damage.

Squirrel damage starts in August when pecans are still in the milk stage. Most of their damage (75-85%) occurs from mid-August through September. Damage then decreases and continues at low levels until harvest. In 1981, damage in the first 3 periods was probably higher by 2-4 kg/ha (early damage characteristics were unknown). Most pecans damaged early are fruit under 2.0 cm. These pecans are punctured, and the squirrels eat the liquid endosperm. After cotyledons develop, pecans are girdled if shucks are still present, and gnawed open on either side (figure 1). Pecans are often kibbled, but gnaw marks can be found on pieces.

Squirrels damage all size classes of pecans, especially those under 4.0 cm (Table 3). Many of the pecans they damage are not fully mature which increases the number of pecans they damage under 3.0 cm. Squirrels also prefer certain cultivars over others (Murray 1975). This suggests that a taste or nutritional preference as well as some size limitation exists in their choice of pecans.

Squirrel damage was much different between 1981 and 1982 (Table 2) which reflected the availability of acorns. Squirrels depredated 6.4 kg/ha or 0.6% of the total production in 1981. In 1982, damage increased to 46.1 kg/ha representing 7.2% of the crop. In cultivar orchards of Louisiana, squirrel depredation was estimated at 0.04% of the total pecan crop (Murray 1975).

In our opinion, squirrel control in orchards is probably best accomplished by a combination of trapping and shooting. Size $1^1/_2$ leg-hold traps placed on 'L-shaped' 2" x 4"s nailed to trunks of trees 1-2 m above the ground, and baited with peanut butter, aluminum, etc.,

are very effective (Reed 1973). The best time to use traps would be in spring when other foods are unavailable. Shooting would be best accomplished during late spring and summer when juveniles are not so wary, and at harvest when trees are shook.

Woodpeckers

Six species of woodpeckers depredated pecans: red-headed, red-bellied, hairy, downy and pileated woodpeckers, and common flickers. Yellow-bellied sapsuckers were in the orchards, but damage was not documented. They more notably drilled parallel holes in trees for sap. Of the woodpeckers, red-headed and red-bellied woodpeckers were considered the major depredators. The others occurred at such low frequencies that they could only do minimal damage.

Woodpecker damage starts in September just prior to ripening, and peaks in late October (figure 2). Most damage occurs as a hole in the face of a pecan (figure 1). Beak marks can be found around the hole or on chipped pieces. Sometimes the pecan is broken into several pieces, but most times a top and bottom end with side pieces can be found. Woodpeckers damaged 7.3 kg/ha or 0.6% of the total production in 1981, and 19.9 kg/ha or 3.3% of the total production in 1982 (Table 2).

Woodpeckers get pecans in trees or off the ground, and fly to a branch (verticle or horizontal) where they secure the pecan in bark grooves. They then hammer at the pecan. Sometimes pecans are opened on the ground, especially by downy woodpeckers. The nutmeat is not always completely consumed. Woodpeckers seem to prefer small pecans (<4.0cm), but will damage all size classes (Table 3).

Woodpeckers cache pecans usually within their own territories

(Kilham 1963). In our study areas, territories were small (<1 ha), and woodpeckers did not fly great distances to cache pecans. Because of this, caching was poorly accounted for by the flight-line counts used. Woodpeckers were only noted to cache 0.37 kg/ha in 1982 and nothing in 1981.

Territoriality was a commonly seen behavior in orchards. Red-headed woodpeckers are the most territorial of all (Reller 1972). They have been found to defend their territories intraspecifically as well as interspecifically from other woodpeckers, blue jays and nuthatches (Kilham 1958, Reller 1972). Other woodpeckers are territorial, but not to the extent as red-headed woodpeckers.

Woodpecker population densities are usually low in orchards because of their territorial behaviors. Woodpecker densities averaged 1.77 birds/ha in 1981 and 1.68 birds/ha in 1982. Red-headed and red-bellied woodpecker abundances in orchards during 1981 averaged 0.93 birds/ha and 0.32 birds/ha, and in 1982 averaged 0.22 birds/ha and 1.08 birds/ha, respectively. As red-headed woodpeckers migrated into orchards, population densities of red-bellied woodpeckers decreased. In 1982, most red-headed woodpeckers did not arrive until late October. Thus, their average densities were lower in 1982.

Woodpecker damage corresponds with insect availability and to a lesser extent with wild mast production. Minimal damage occurred early in 1981 because insects were abundant. From 22 collected woodpeckers in 1981, insects were the primary food item in their diets in late September and early October. Then when insect abundance decreased, nutmeat consumption in diets increased. In 1982, damage started about September 20. From 49 collected woodpeckers, few insects were found in

their diets. Nutmeat was the primary food item in gizzards.

Woodpecker control is probably best met with shotgun patrols. Very few other methods seem effective for woodpeckers. During years of good insect availability, though, woodpeckers probably do growers more good than harm because they consume large quantities of insects.

Crows

Crows are not much of a factor in total wildlife depredation in native pecan orchards. Most of their damage occurs with larger size classes of pecans (Table 3), or in cultivar orchards. Damage by crows in 1981 was estimated at 2.1 kg/ha and in 1982 at 5.4 kg/ha which represented 0.2% and 0.9% of the total production of pecans (Table 2). Therefore, crow damage was not significant in these orchards. Murray (1975) reported crows damaging 5.8% of the total crop in 1973 in Louisiana cultivar orchards. This suggests that crows are greater depredators in cultivar orchards.

Crows damage pecans by hammering at the face, usually breaking it into several pieces. Large beak mark indentations can be found on pieces (figure 1). Crows also cache pecans, but not as extensively as blue jays. Pecans are not the major food item in their diets when other food sources such as insects and wild mast are available. From 4 crows collected in early October of 1981, insects and poison ivy (Rhus radicans) seeds were the major dietary items. From 2 more crows collected later in 1981 and 7 collected in 1982, nutmeats were the primary food item found.

Crows are commonly seen in flocks in orchards. Population averages from time-area counts were 0.73 crows/ha in 1981 and 1.34 crows/ha in

1982. Fish crow have also been found to damage pecans within their range (Murray 1975). They flock with common crows and have similar damage characteristics.

Control for crows has been reasonably successful. Probably the best method of control is the use of Avitrol (Wilson 1974). Sound-scare devices in conjunction with shooting also seems to be fairly effective (Dyer 1954, Wilson 1974).

Small Rodents

Three rodents which caused damage were found in the orchard: eastern woodrats, hispid cotton rats and white-footed mice. Deer mice were not found, but were suspected to be in the study areas. In other regions, several other small rodents may do damage (Table 1).

Small rodents consistently damage at low levels following nut drop throughout the fall. Damage was estimated at 1.1 kg/ha in 1981 and at 1.2 kg/ha in 1982 (Table 2). Caching was not included in these figures. Caches were commonly found at the base of trees in the orchard and among brush piles in adjacent cover. Captive white-footed and deer mice ate approximately 0.8 pecans/day, and hispid cotton rats ate about 2.0 pecans/day.

Small rodent damage can be identified easily. White-footed mice open a hole in the face of a pecan, whereas rats, deer mice and house mice open pecans at the top or bottom (figure 1). Periodically, deer mice open pecans near the middle. Small groove marks from gnawing can be found around the hole for positive identification, separating small rodent damage from bird and squirrel damage.

Rats are commonly found adjacent to orchards in brush piles and

similar cover. If the orchard is not mowed or brush piles are in the orchard, they will inhabit these areas as well. Mice are frequently found in orchards. They use cavities in trunks of trees for their homes.

Dense populations of small rodents can be controlled with several different poisons available on the market (Kennamer 1959). Zinc phosphide appears to be the most effective. Rodenticides must be applied with care.

White-tailed Deer

Deer can be found around most orchards if escape cover is plentiful. Deer damage is minimal throughout the season. Deer damage was not found in plots in 1981, and in 1982, damage was estimated at 0.11 kg/ha. Their damage is hard to recognize except by tracks because they crush pecans and only pieces can be found. It is very similar to cow and carnivore damage. Since deer hunting is a popular sport, their damage is often tolerated.

Other Birds

Several other avian species consumed pecans in this study, but their damage was not measured and was included in the wildlife unknown category of damage. Relevant data for these species will be discussed.

Mallards and wood ducks were found in few numbers in aquatic areas near orchards. They eat pecans whole so their damage could not be measured. These species eat large amounts of small pecans at a time, ie. a wood duck was collected which had 17 pecans (all <3.0cm) and 7 acorns in its crop with more crushed pecans in its gizzard. Damage,

however, was considered negligible (<1%) in study areas. In areas such as Louisiana where larger concentrations of waterfowl exist, and where orchards become flooded frequently, waterfowl may be more of a problem.

Bobwhites and turkeys occurred in areas around orchards in low numbers. They damage pecans primarily around the perimeter of orchards. They eat pecans whole, so their damage was not measured. Turkeys can do a lot of damage in a single feeding, ie. 19 turkeys were feeding under trees with plots; after a ground scan of the area only a few pecans were found, although many pecans were known to be there beforehand. Damage was considered insignificant (<1%), because of low population numbers. Turkey, bobwhite and waterfowl damage is often tolerated because they are considered popular game species.

Small birds, Carolina chickadees, tufted titmice and white-breasted nuthatches did damage to thin-shelled pecans, especially when insects were unavailable. Their average densities were 0.94 birds/ha in 1981 and 1.28 birds/ha in 1982. They damage pecans by opening a small hole in the face, and they rarely finish the nutmeat. Damage is not restricted to small pecans as they were seen damaging large pecans on the ground. From a chickadee and a nuthatch collected, nutmeat was found in their gizzards. A titmouse was seen carrying off a small pecan. These birds probably caused about 1% damage in 1982 when insects were unavailable. In 1981, however, little evidence of damage was found. Also, brown-headed and red-breasted nuthatches are common in southeastern states and may do damage.

Mourning doves, starlings, eastern meadowlarks, red-winged blackbirds and common grackles were seen in the orchard, especially after the initiation of harvest operations. These species primarily

consumed already damaged pecans. They were commonly seen foraging for broken pecans after harvest. From collected birds, nutmeat was found in gizzards, but they were never seen breaking open pecans. Grackles probably break open small thin-shelled pecans because they have been found to crack acorns with direct pressure (Bent 1965). In our study and others (Murray 1975, Leppla 1980), many grackles were seen, but never breaking open pecans.

Other Mammals

Many other mammalian species were present in the orchard which did damage. A few species can do extensive damage in areas where their population densities are high. In this study, their damage was not monitored because of the difficulty in determining which species was actually responsible.

Opossums and raccoons are probably the most significant depredators of the remaining mammals. Opossum damaged 1-2% of the total pecan crop at one orchard in 1982. Raccoons in some areas also can do considerable damage (Jaynes 1979). Damage was not observed on unripe pecans, so it was assumed that damage starts about October 1. Both climb trees, so their damage may begin prior to ripening. Their damage, like other predators, occurs as crushed pecans. Usually, small teeth holes are left on broken pieces. The best method of control for these species is probably trapping.

Eastern cottontails and swamp rabbits were found in the study areas in brush piles adjacent to orchards. They were not observed consuming pecans, but crushed pecans could be found near heavily populated areas. Other researchers have found them to do damage (Martin et al. 1951,

Jaynes 1979). Their greatest damage is to newly planted seedlings during winter months. The best method of control for this is fencing. Also, other species of rabbits are found within the cultural range of pecans which may do damage.

Coyotes, gray foxes and domestic dogs occurred in orchards in low numbers. Canid damage is unrecognizable except by tracks because pecans are crushed into several pieces by molars. Canids only periodically supplement their diet with vegetable matter (Martin et al. 1951), so their damage was probably insignificant. A coyote and domestic dog were seen eating pecans. Leppla (1980) also observed a coyote eating a pecan. Gray foxes were not seen, but were probably in study areas. Martin et al. (1951) found that pecans are a small part of the gray fox diet.

Striped skunks were commonly found in orchards. It was unknown if they did any damage, although fruits are a common part of their diet. Other species of skunks are also found in the cultural range of pecans and their damage is unknown.

Black bears have been found to damage pecans in the southeast (Martin et al. 1951). Beavers and woodchucks damage trees (Jaynes 1979). And lastly, armadillos are considered a nuisance to normal orchard maintenance because they dig burrows. Other species may elsewhere create problems for growers.

Conclusion

Pecan growers in the United States must deal with several potential depredators. Several factors regulate the severity of damage. Probably the most important factor in the severity of wildlife damage is the

availability of alternate food sources. When available, acorns and insects are chief constituents of the diets of many depredating birds and mammals. In our study, wildlife damage was inversely related to acorn production and insect availability in 1981 and 1982.

Pecan production itself influences the per cent of damage. Damage percentages will be lower for the same amount of damage, if more pecans are produced. Population levels of different species also affects amount of damage. This is influenced by geographic location and reproductive success. Geographic location is especially important in migratory birds. For example, a major migration corridor, north-south, transects central Oklahoma and more blue jays occur there. On the other hand, reproductive success is especially important in non-migratory birds and mammals, ie. if the population of an area increases, damage can be expected to increase.

Lastly, the range of a species and type of pecan grown determine which species growers must control. For example, Oklahoma native pecan growers must concern themselves with blue jays whereas New Mexico cultivar growers might be concerned with ravens.

Research Needs

Many species (Table 1) are possible pecan depredators. A list of definite pecan depredators would be beneficial to animal damage control agents and growers to determine control tactics for orchards in different areas. A list of expected damage losses and best control methods for each species would be helpful.

Wildlife damage to pecans can only be estimated. We estimate that 21 million dollars are lost at current market prices (averaged for 1981

and 1982) to depredators. A better estimate than ours is needed, but would entail a national survey. The survey would have to be conducted over a period of years because of the variability in wildlife damage between years. Such a survey would help determine the need for future animal damage control research in pecan orchards.

Literature Cited

Batcheller, G. R. 1980. The ecology and behavior of blue jays in Oklahoma. M. S. thesis, Okla. State Univ., Stillwater. 45 pp.

Bent, A. C. 1965. Life histories of North American blackbirds, orioles, tanagers, and allies. Dover Publ., Inc., New York. 549pp.

Carlton, R. L. 1975. Birds and animal damage control in pecans. Pecan South 2:5, 214-216.

Couch, G., G. Hedger, J. Watson and B. Peterson. 1977. Wildlife control panel. Okla. Pecan Growers Assoc. Proc. 47:39-46.

Darley-Hill, S. and W. C. Johnson. 1981. Acorn dispersal by the blue jay (Cyanocitta cristata). Oecologia (Berlin) 50:231-232.

Dyer, R. 1954. Controlling crows with rope and firecrackers. Okla. Pecan Growers Assoc. Proc. 24:3-6.

Hall, T. C. and M. W. Smith. 1984. Evaluation of two wildlife control techniques in Oklahoma pecan orchards. Pp. 18-37 in T. Hall. Wildlife damage and control in Oklahoma pecan orchards. M. S. thesis, Okla. State Univ., Stillwater. 69pp.

Jaynes, R. A. 1979. Nut tree culture in North America. Northern Nut Growers Assoc., Inc. 466 pp.

Kennamer, E. F. 1959. Best methods of controlling crows and other

pests in pecans. SE Pecan Growers Assoc. Proc. 52:32-35.

Kilham, L. 1958. Territorial behavior of wintering red-headed woodpeckers. Wilson Bull. 70:347-358.

Kilham, L. 1963. Food storing of red-bellied woodpeckers. Wilson Bull. 75:227-234.

Lamb, W. A., A. H. Kelley and S. M. Cohen. 1978. Age determination of blue jays. Bird-banding 49:215-217.

Leppla, R. R. 1980. An assessment of damage to pecans by wildlife in central Oklahoma. M. S. thesis, Okla. State Univ., Stillwater. 71pp.

Livingston, R. L. 1973. Pecans in Georgia. Coop. Ext. Serv., Univ. Georgia, Athens. Bull. 609. 23pp.

Martin, A. C., H. S. Zim and A. L. Nelson. 1951. American wildlife and plants. McGraw-Hill Book Co., New York. 500pp.

Murray, M. L. 1975. An assessment of damage to Louisiana pecan orchards by the common crow (Corvus brachyrhynchos). M. S. thesis, Louisiana State Univ., Baton Rouge. 45pp.

Norris, R. A. 1961. A modification of the Miller method of aging live passerine birds. Bird-banding 32:55-57.

Reed, D. 1973. Trapping squirrels. Okla. Pecan Growers Assoc. Proc. 43:29.

Reller, A. W. 1972. Aspects of behavioral ecology of red-headed and red-bellied woodpeckers. Am. Midl. Nat. 88:270-290.

Shafer, C. E. and B. H. Bailey. 1978. Projected pecan production. Pecan Quarterly 12:9-10.

Smith, C. C. and D. Follmer. 1972. Food preferences of squirrels. Ecology 53:82-91.

Wilson, R. C. 1974. An assessment of crow control techniques in pecan orchards of Louisiana. M. S. thesis, Louisiana State Univ., Baton Rouge. 83pp.

Table 1. Pecan pests and secondary pecan consumers in the United States.

KNOWN DEPREDATORS	
* Mallard	*Anas platyrhynchos*
* Wood duck	*Aix sponsa*
* Wild turkey	*Meleagris gallopavo*
* Northern bobwhite	*Colinus virginianus*
* Northern flicker	*Colaptes auratus*
* Pileated woodpecker	*Dryocopus pileatus*
* Red-bellied woodpecker	*Melanerpes carolinus*
* Red-headed woodpecker	*Melanerpes erythrocephalus*
* Hairy woodpecker	*Picoides villosus*
* Downy woodpecker	*Picoides pubescens*
* Blue jay	*Cyanocitta cristata*
* American crow	*Corvus brachyrhynchos*
Fish crow	*Corvus ossifragus*
* Carolina chickadee	*Parus carolinensis*
* Tufted titmouse	*Parus bicolor*
* White-breasted nuthatch	*Sitta carolinensis*
* Virginia opossum	*Didelphis virginiana*
Black bear	*Ursus americanus*
* Raccoon	*Procyon lotor*
* Eastern cottontail	*Sylvilagus floridanus*
* Swamp rabbit	*Sylvilagus aquaticus*
Eastern chipmunk	*Tamias striatus*
* Gray squirrel	*Sciurus carolinesis*
* Eastern fox squirrel	*Sciurus niger*
* Plains pocket mouse	*Perognathus flavescens*
* White-footed mouse	*Peromyscus leucopus*
* Hispid cotton rat	*Sigmidon hispidus*
* Eastern woodrat	*Neotoma floridana*
* Coyote	*Canis latrans*
* Gray fox	*Urocyon cinereoargenteus*
* White-tailed deer	*Odocoileus virginianus*
* Domestic dog, cow, pig	
POSSIBLE DEPREDATORS	
* American black duck	*Anas rubripes*
* Northern pintail	*Anas acuta*
Montezuma quail	*Cyrtonyx montezumae*
Band-tailed pigeon	*Columba fasciata*
Red-billed pigeon	*Columba flavirostris*
* Rock dove	*Columba livia*
Ladder-backed woodpecker	*Picoides scalaris*
**Red-cockaded woodpecker	*Picoides borealis*
Golden woodpecker	*Melanerpes aurifrons*
Acorn woodpecker	*Melanerpes formicivorus*
Lewis' woodpecker	*Melanerpes lewis*
Steller's jay	*Cyanocitta stelleri*

Table 1. (cont.)

Scrub jay	Aphelocoma coerulescens
Gray-breasted jay	Aphelocoma ultramarina
Pinyon jay	Gymnorhinus cyanocephalus
Clarke's nutcracker	Nucifraga columbiana
Chihuahuan raven	Corvus cryptoleucus
Plain titmouse	Parus inornatus
Bushtit	Psaltriparus minimus
* Red-breasted nuthatch	Sitta canadensis
Brown-headed nuthatch	Sitta pusilla
Pygmy nuthatch	Sitta pygmaea
* Great-tailed grackle	Quiscalus mexicanus
* Common grackle	Quiscalus quiscula
* Brown thrasher	Toxostoma rufum
* Rufous-sided towhee	Pipilo erythrophthalmus
Brown towhee	Pipilo fuscus
* Eastern spotted skunk	Spilogale putorius
* Striped skunk	Mephitis mephitis
Hooded skunk	Mephitis macroura
Eastern hognosed skunk	Conepatus leuconotus
* Red fox	Vulpes vulpes
Rock squirrel	Spermophilus variegatus
* Southern flying squirrel	Glaucomys volans
Botta's pocket gopher	Thomomys bottae
* Plains pocket gopher	Geomys bursarius
Texas pocket gopher	Geomys personatus
Souteastern pocket gopher	Geomys pinetus
Yellow-faced pocket gopher	Pappogeomys castanops
Silky pocket mouse	Perognathus flavus
* Hispid pocket mouse	Perognathus hispidus
* Eastern harvest mouse	Reithrodontomys humulis
* Plains harvest mouse	Reithrodontomys montanus
Western harvest mouse	Reithrodontomys megalotis
* Fulvous harvest mouse	Reithrodontomys fulvescens
Oldfield mouse	Peromyscus polionotus
* Deer mouse	Peromyscus maniculatus
* Cotton mouse	Peromyscus gossypinus
* Brush mouse	Peromyscus boylii
White-ankled mouse	Peromyscus pectoralis
Florida mouse	Peromyscus floridanus
Golden mouse	Peromyscus nuttalli
Northern pygmy mouse	Baiomys taylori
Southern plains woodrat	Neotoma micropus
White-throated woodrat	Neotoma albigula
Mexican woodrat	Neotoma mexicana
* Marsh rice rat	Oryzomys palustris
Arizona cotton rat	Sigmidon arizonae
* Woodland vole	Microtus pinetorum
* Norway rat	Rattus norvegicus
* Black rat	Rattus rattus
* House mouse	Mus musculus
* Meadow jumping mouse	Zapus hudsonius
Woodland jumping mouse	Napaeozapus insignis

Table 1. (cont.)

Desert cottontail	*Sylvilagus audubonii*
Marsh rabbit	*Sylvilagus palustris*
Wild pig	*Sus scrofa*
Mule deer	*Odocoileus hemionus*
ORCHARD MAINTENANCE PESTS	
* Yellow-bellied sapsucker	*Sphyrapicus varius*
Williamson's sapsucker	*Sphyrapicus thyroideus*
* Eastern mole	*Scalopus aquaticus*
* Beaver	*Castor canadensis*
Porcupine	*Erethizon dorsatum*
* Nine-banded armadillo	*Dasypus novemcinctus*
Woodchuck	*Marmota monax*
SECONDARY PECAN CONSUMERS	
White-winged dove	*Zenaida asiatica*
* Mourning dove	*Zenaida macroura*
Ground dove	*Columbina passerina*
* American robin	*Turdus migratorius*
* Eastern meadowlark	*Sturnella magna*
Western meadowlark	*Sturnella neglecta*
* Red-winged blackbird	*Agelaius phoeniceus*
* Rusty blackbird	*Euphagus carolinus*
Brewer's blackbird	*Euphagus cyanocephalus*
* Brown-headed cowbird	*Molothrus ater*
* Rose-breasted grosbeak	*Pheucticus ludovicianus*
Evening grosbeak	*Coccothraustes vespertina*

* species found in Oklahoma
**endangered species found in Oklahoma

Table 2. Estimated kg/ha pecan production and damage losses in 1981 and 1982 in native pecan orchards in Oklahoma.

County	Okmulgee	Marshall*	Okmulgee	Marshall
Year	1981	1981	1982	1982
n (fields)	2	2	2	3
Total Production	1136	1354	768	472
	SUBDIVISIONS OF TOTAL PRODUCTION			
Undamaged Pecans	869	963	413	166
Orchard Loss	236	377	202	112
Wildlife Damage	31	14	153	194
	SUBDIVISIONS OF WILDLIFE DAMAGE			
Blue Jay Damage	1.21	-	18.93	16.73
Blue Jay Caching	0	-	11.18	95.22
Squirrel Damage	6.42	-	64.21	28.02
Woodpecker Damage	7.32	-	23.07	16.80
Crow Damage	2.13	-	8.98	2.92
Rodent Damage	1.11	-	0.98	1.37
Deer Damage	0	-	0.21	0
Unknown Wildlife	13.36	-	25.80	32.32

*The final damage assessments were not completed, so these figures were estimated from incomplete data.

Table 3. Number of pecans damaged in 5 size classes by blue jays, squirrels, woodpeckers and crows compared with the frequency of that size class found in native pecan orchards in Oklahoma. From pecans sampled in ground plot assessments in 1982.

SIZE CLASS (cm)	<3.0	3.0-3.5	3.5-4.0	4.0-4.5	>4.5
TOTAL PECANS SAMPLED	9854	2673	257	423	177
BLUE JAY					
No. Pecans Damaged	214	62	6	0	1
% of Total Sampled	2.2	2.3	2.3	0	0.6
SQUIRREL					
No. Pecans Damaged	1090	159	17	12	1
% of Total Sampled	11.1	6.0	6.6	2.8	0.6
WOODPECKER					
No. Pecans Damaged	247	89	8	1	2
% of Total Sampled	2.5	3.3	3.1	0.2	1.1
CROW					
No. Pecans Damaged	3	5	3	31	23
% of Total Sampled	<0.1	0.2	1.2	7.1	13.0

Table 4. Diameter at breast height (DBH) (ave. 46.7cm ± 19.5cm) and height (ave. 16.4m ± 4.9m) of tree compared with blue jay damage in Okmulgee County, Oklahoma in 1982.

DBH (cm)	No. Trees (n)	Damage (g/tree)
< 25	17	43
26-35	8	136
36-45	11	1073
46-55	21	443
56-65	9	657
> 66	14	462
HEIGHT (m)	**No. Trees (n)**	**Damage (g/tree)**
7-9	7	107
10-12	15	105
13-15	9	83
16-18	23	686
19-21	14	599
22-27	12	710

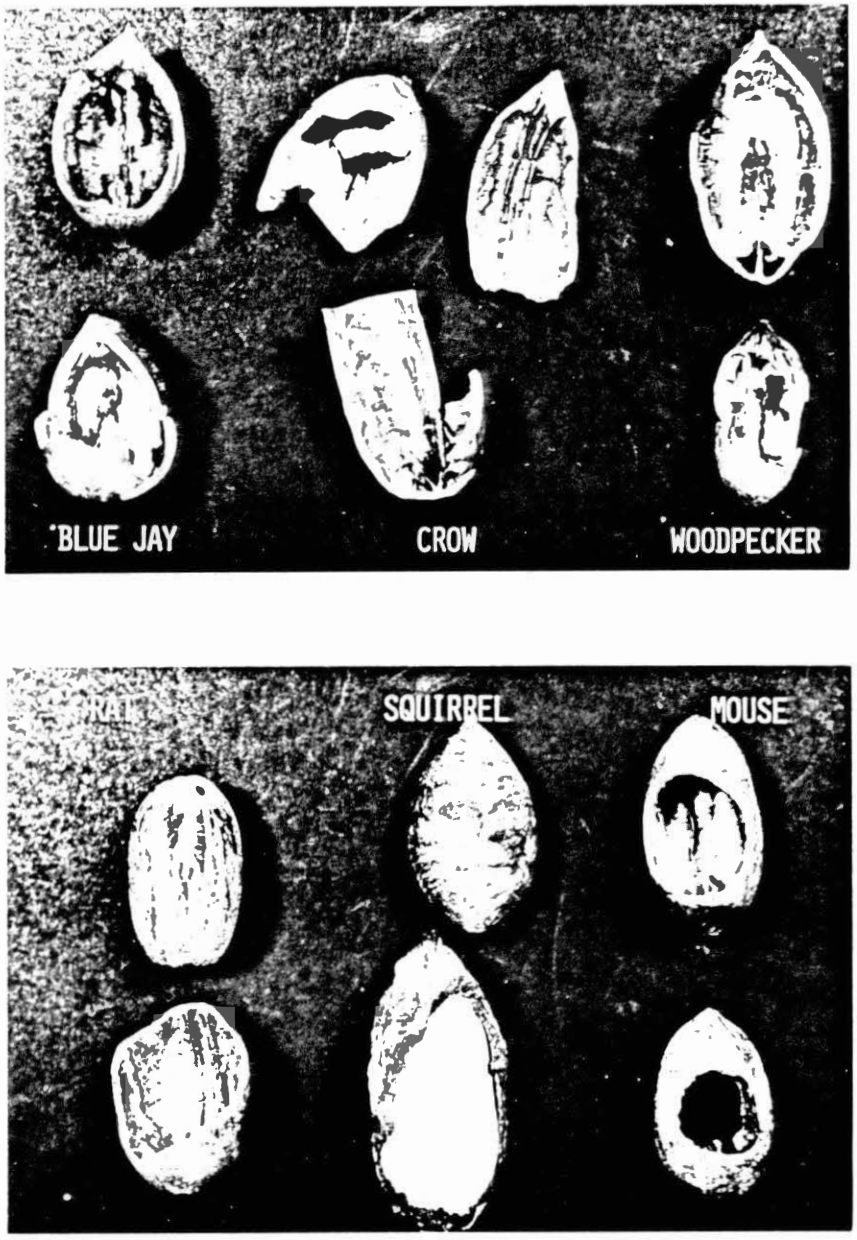

Figure 1. Blue jay, common crow, woodpecker, rat, squirrel and white-footed mouse damage to pecans.

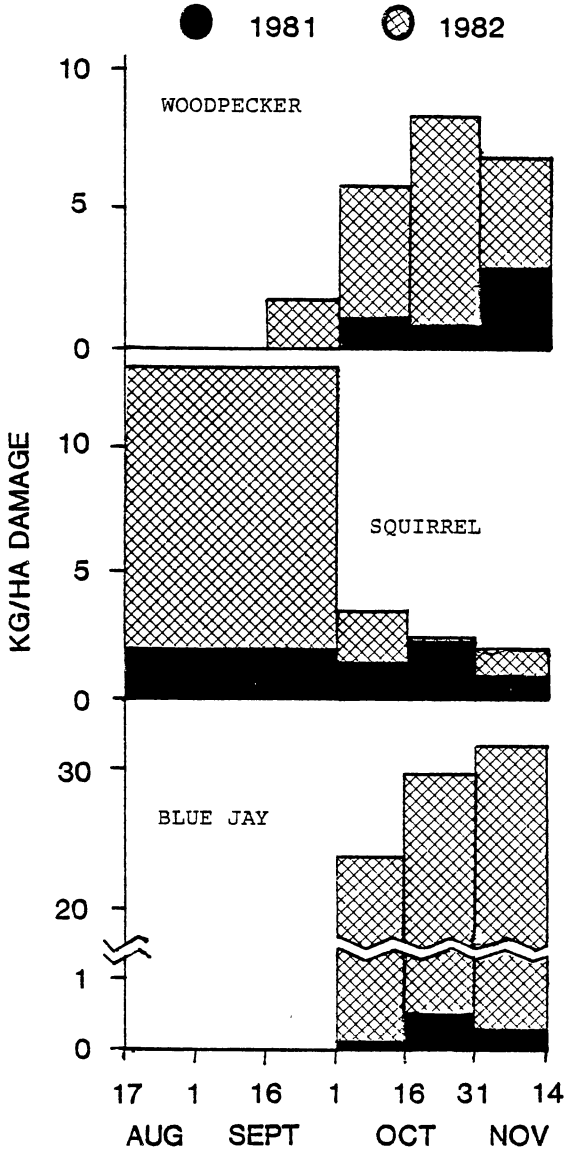

Figure 2. Blue jay, squirrel and woodpecker damage losses for 15 day intervals in 1981 and 1982 in Oklahoma native pecan orchards. Squirrel damage rates for the first three intervals were unknown; therefore, the cumulative damage for 45 days (approximate damage days before Oct. 1) was divided by three for average loss in these intervals.

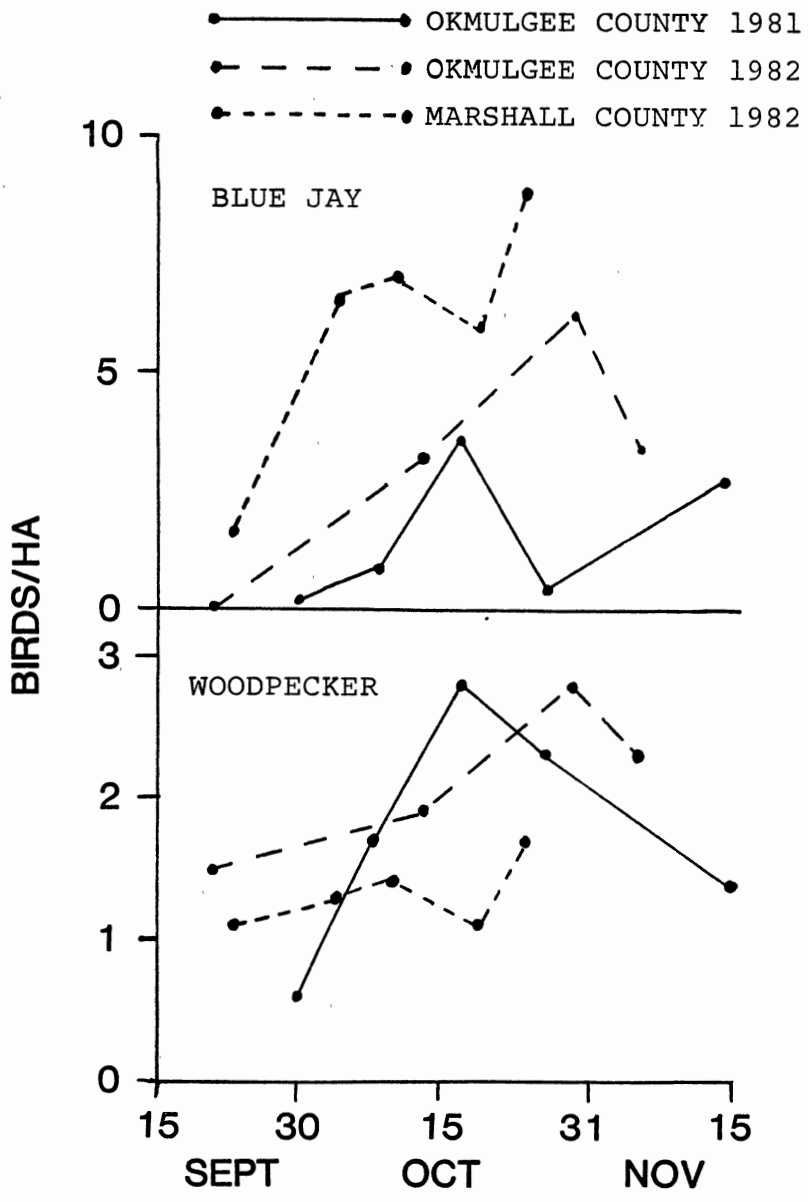

Figure 3. Blue jay and woodpecker population levels in time-area counts (n=3 counts/date) in native pecan orchards in Oklahoma in 1981 and 1982.

VITA 2

Thomas Christopher Hall

Candidate for the degree of

Master of Science

Thesis: WILDLIFE DAMAGE AND CONTROL IN OKLAHOMA PECAN ORCHARDS

Major Field: Wildlife Ecology

Biographical:

Personal Data: Born in Denver, Colorado, April 1, 1957, the son of Dr. Louis A. and Jeanette Hall.

Education: Graduate of Machebeuf High School, Denver, Colorado, May 1975; received the Bachelor of Arts degree in Psychology and the Bachelor of Science degree in Biology (Natural History) from Fort Lewis College, Durango, Colorado, May and August 1979, respectively; completed the requirements for the Master of Science degree in Wildlife Ecology at Oklahoma State University, Stillwater, Oklahoma, July 1984.

Professional Experience: Student Aide, conducted bird counts, United States Forest Service, Durango, Colorado, 1978-1979. Wildlife Technician, United States Fish and Wildlife Service (USFWS), Washington, D. C., 1979. Wildlife Technician, USFWS, Denver, Colorado, 1979-1980. Wildlife Technician, USFWS, West Hope, North Dakota, 1980. Wildlife Technician, USFWS, Denver, Colorado, 1980-1981. Graduate Research Assistant, Oklahoma Cooperative Wildlife Research Unit, Oklahoma State University, Stillwater, Oklahoma, 1981-1982. Range Manager, Outdoor Horizons Inc., Broomfield, Colorado, 1982-1983.

Professional Societies: Member of the Wildlife Society, Colorado Wildlife Federation, National Rifle Association.